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Description

Heat Sink Riveted to Memory Module with Upper Slots and Open Bottom Edge for Air Flow

BACKGROUND OF INVENTION

[0001] This invention relates to heat sinks, and more particularly to heat sinks for memory modules.

[0002] Heat sinks have been widely used to assist in cooling electrical components. Some microprocessors have heat sinks attached to allow for higher-frequency operation. Other components such as memory modules may also benefit from heat sinks.

[0003] Most personal computers (PC's) are shipped with sockets for memory modules so that their owners can later add additional modules, increasing the memory capacity of the PC. Other non-PC devices may also use memory modules designed for PC's. High-volume production and competition have driven module costs down dramatically, benefiting the buyer.

[0004] Memory modules are made in many different sizes and capacities, with the older 30-pin modules replaced by 72-pin, 168-pin, and other size modules. The "pins" were originally pins extending from the module's edge, but now most modules are leadless, having metal contact pads, fingers, or leads. The modules are small in size, some being about 5.25 inches long and 1.2 or 1.7-inches high.

[0005] The modules contain a small printed-circuit board (PCB) substrate, typically a multi-layer board with alternating laminated layers of fiberglass insulation and foil or metal interconnection layers. Surface mounted components are soldered onto one or both surfaces of the substrate. Memory integrated circuits (IC's) or chips are commonly packaged in inexpensive surface-mount packages such as small-outline J-leaded (SOJ) packages, plastic leaded chip carriers (PLCC's), thin small-outline packages (TSOP) or small-outline (SO) packages. The number of memory chips in a module depends on the capacity and the data-width of the memory chips and the size of the memory module.

[0006] Figure 1 is a diagram of a memory module with dynamic-random-access memory (DRAM) chips. The memory module contains substrate 10, with surface-mounted DRAM

chips 20 mounted directly to the front surface or side of substrate 10, while more DRAM chips (not visible) are usually mounted to the back side or surface of substrate 10. Metal contact pads 12 are positioned along the bottom or connector edge of the module on both front and back surfaces. Metal contact pads 12 mate with pads on a module socket to electrically connect the module to a PC's motherboard. Holes and/or notches 14, 16 are sometimes used to ensure that the module is correctly positioned in the socket. For example, notch 14 can be offset from the center of substrate 10 to ensure that the memory module cannot be inserted backwards in a socket. Notches 16 match with clamps of the module socket to ensure that module is securely positioned in the socket.

[0007] As processor speeds have increased, the need for faster memory has become more critical. Various bandwidth-enhancing methods and memory interfaces have been used. Memory chips have higher densities and operate at higher frequencies than before, producing more waste heat from the memory chips. There is a need to remove this waste heat from memory modules.

[0008] Various heat sinks designed for memory modules are known. See for example U.S. Patent Nos. 6,362,966,

6,424,532, and 6,449,156, among others. Clamp-on heat sinks for memory modules are also known. For example, Corsair Memories makes a heat sink that fits over the front and back surfaces of a memory module and is held in place by a wire clip over the top edge. OCZ Technology produces a copper heat sink with wider metal bands that clip the heat sink to over the front and back surfaces of the memory module. While useful, these clip-on and clamp-on designs can exhibit a flimsiness or lack of rigidity that can make the memory modules appear cheaply made.

[0009] Some memory-module heat sinks feature a closed-top design that prevents air flow in the small gaps between the heat sink and the memory module substrate. Often the entire top edge of the heat sink is closed, providing no path for air to flow under the heat sink other than back out the bottom edge, which is usually open. Sides may be open or partially open, but the sides are much smaller than the top and bottom edges of the memory module, limiting the possible air flow.

[0010] What is desired is a heat sink designed specifically for memory modules. A rigidly attached heat sink for memory modules is desirable. A heat sink with a more efficient air

flow across memory chips on a memory module is also desirable.

Brief Description of Drawings

[0011] Figure 1 is a diagram of a memory module with DRAM chips.

[0012] Figure 2A shows a heat sink with top slots before attachment to a memory module.

[0013] Figure 2B shows the heat sink with the top slots after attachment to a memory module.

[0014] Figures 3A-D show other views of the heat sink attached to the memory module.

[0015] Figure 4 shows open sides and closed sides of the heat sink.

[0016] Figure 5 highlights improved air flow under the heat sink plates and out through the top-edge slots.

[0017] Figures 6A-B show an alternate embodiment with larger top openings.

Detailed Description

[0018] The present invention relates to an improvement in memory modules. The following description is presented to enable one of ordinary skill in the art to make and use the invention as provided in the context of a particular appli-

cation and its requirements. Various modifications to the preferred embodiment will be apparent to those with skill in the art, and the general principles defined herein may be applied to other embodiments. Therefore, the present invention is not intended to be limited to the particular embodiments shown and described, but is to be accorded the widest scope consistent with the principles and novel features herein disclosed.

[0019] The inventors have realized that riveting a heat sink to a memory module substrate can produce a rigid, sturdy all-in-one memory module/heat sink. Riveting allows the heat sink to be firmly and snugly attached to the memory module substrate.

[0020] The inventors have further realized that cooling efficiency can be improved by allowing for air flow under the heat sink, between the heat sink and the memory module substrate. Even though this area between the heat sink and substrate is small and mostly occupied by the memory chips, small gaps between pairs of memory chips can channel air flow past the memory chips, directly cooling them as well as cooling the heat sink from both the under-side and the large, exposed top surface of the heat sink.

[0021] The inventors encourage this air flow through the tiny channels between memory chips by adding slots in the heat sink near the top edge of the memory module. These top-edge slots allow air to escape from between the memory module substrate and the heat sink. Air can enter the gaps between the heat sink and the PCB substrate from the open bottom edge near the connectors, and can flow between the memory chips and out the top-edge slots. Stagnant air under the heat sink is reduced, allowing the heat sink to be cooled by air flow across both the outer open surface of the heat sink, and the hidden underside surface of the heat sink that contacts the tops of the memory chips.

[0022] Figure 2A shows a heat sink with two top slots before attachment to a memory module. Two heat-sink plates 30 are used, one for the front surface of the memory module, and the other for the back surface of the memory module. The two plates 30 are held to the memory module substrate and to each other by rivets 24 that fit in holes in plate 30. The upper-side of the upper plate 30 is shown. This upper-side generally fits over the front surface of the memory module shown in Fig. 1.

[0023] Plate 30 contains raised ridge 22 that surrounds depres-

sion 21. Depression 21 is closer to the surface of the memory module substrate when attached. The underside of depression 21 makes contact with the flat top surfaces of memory chips 20 of Fig. 1. Decal 28 or other markings can be placed in depression 21.

[0024] Two top-edge slots 26 are formed in plate 30 near the top edge. Top-edge slots 26 are holes in plate 30 that allow air to pass through. Top-edge slots 26 can be formed on the sloping part of plate 30 above raised ridge 22, between raised ridge 22 and top attachment portion 23. Top attachment portion 23 is closer to PCB substrate 10 than depression 21, which is closer to the PCB substrate than raised ridge 22.

[0025] Three rivets 24 are fastened to top attachment portion 23, one between top-edge slots 26 and one in each top corner of substrate 10. A fourth rivet 24 is located near the center of the bottom (connector) edge of substrate 10.

[0026] Figure 2B shows the heat sink with the top slots after attachment to a memory module. Upper plate 30 is fixedly attached to the front surface of PCB substrate 10 of the memory module by rivets 24. Three rivets 24 near the top edge press top attachment portion 23 against the surface of substrate 10, making a firm, sturdy assembly. A fourth

rivet 24 near the center of the bottom edge passes through substrate 10, but plate 30 does not make contact with substrate 10 near this fourth rivet. The fourth rivet 24 provides added stability of the mounting of plate 30 (and another plate 30', not shown, attached to the back surface of substrate 10) to substrate 10.

[0027] Plate 30 ends before contact pads 12 along the lower edge of substrate 10, allowing these contact pads 12 to be freely inserted into a memory module socket. Notch 14 is offset from center, while edge notches 16 are on the right and left edges of substrate 10. As shown by comparing Fig. 2A to Fig. 2B, the sides of plate 30 are notched inward near the top of upper notches 16 on the memory module, allowing notches 16 to fit into memory module sockets unencumbered by plate 30.

[0028] Figures 3A-D show other views of the heat sink attached to the memory module. Fig. 3A is a top view showing the top edge of PCB substrate 10 with heat-sink plates 30, 30' attached. Three rivets 24 pass through plates 30, 30' and substrate 10 to rigidly attach plates 30, 30' to substrate 10. Top attachment portion 23 fits snugly with the surface of substrate 10, while raised ridge 22 rises up from top attachment portion 23. Top-edge slots 26 are cut into the

sloping portion of plate 30 between top attachment portion 23 and raised ridge 22. A total of four top-edge slots 26 are provided - two in front plate 30 and two more in back plate 30'. The top edges of memory chips and other components of the memory module may be visible through top-edge slots 26 or may be hidden by the thin layer of top attachment portion 23.

[0029] Fig. 3B is a bottom view showing the bottom edge of PCB substrate 10 with memory chips contacting the heat-sink plates. The bottom edge of the assembly is open, since the metal contact pads are located along the bottom edge of substrate 10. Memory chips 20 and their leads bonded to substrate 10 are visible through the open bottom edge between heat-sink plates 30, 30'. A fourth rivet 24 passes from front plate 30, through a gap and through substrate 10, then through a second gap to back plate 30'. While not as sturdy as the three rivets along the top edge, the fourth rivet provides additional stability, especially for the bottom edges of front plate 30 and back plate 30'.

[0030] Depressions 21 in front plate 30 and back plate 30' make contact with the upper flat surfaces of memory chips 20, providing good heat transfer from the chips to metal heat-sink plates 30, 30'. The sloped edges of plates 30,

30' along the small sides of substrate 10 between notches 16 and the top edge are visible in the background from this view.

[0031] Fig. 3C is a side view showing one of the small sides of the memory module. Notches 16 are cut in the small side edges of substrate 10. The portions of substrate 10 at the backs of notches 16 are not shown for clarity in Fig. 3C. Front plate 30 and back plate 30' are connected together by rivet 24 in the upper right corner of Fig. 2B. Plates 30, 30' make contact with the surface of substrate 10 along the whole top edge and along the upper portion of the side edges, but stop at the first notch 16. Other portions of plates 30, 30' are visible in the background extending downward toward the bottom edge of substrate 10.

[0032] Fig. 3D is a cross-sectional view of the heat-sink plates, memory chips, and module substrate. Rivet 24 clamps top attachment portion 23 of front plate 30 to the front surface of substrate 10, and passes through substrate 10 and also clamps back plate 30' to the back surface of substrate 10 near its top edge.

[0033] The cross-section of front plate 30, starting from the top of Fig. 3D, shows rivets 24 attached through top attachment portion 23, then shows the sloped portion from top

attachment portion 23 out to raised ridge 22. Continuing downward along front plate 30, depression 21 is formed to be closer to substrate 10 than raised ridge 22. Depression 21 makes contact with the flat surfaces of memory chips 20 mounted to substrate 10 by their leads.

[0034] Figure 4 shows open sides and closed sides of the heat sink. Front plate 30 and back plate 30' make contact with substrate 10 along top attachment portion 23, including areas around top three rivets 24. While this blocks air flow, top-edge slots 26 are cut in plates 30, 30' to allow for air flow. These four open top slots allow for air flow past the memory chips under plates 30, 30'.

[0035] Contact between front plate 30 and back plate 30' and substrate 10 also is made along the two side edges from the top corners near corner rivets 24 to the top of upper notches 16. This plate-to-substrate contact also prevents air flow. However, contact is not made below notches 16, so the lower portions of the sides are open, allowing for air flow.

[0036] Front plate 30 and back plate 30' do not make contact with substrate 10 near bottom rivet 24 near connectors or contact pads 12. Instead, an air gap is between plates 30, 30' and substrate 10 near bottom rivet 24 near notch 14.

Thus the entire bottom edge along contact pads 12 is open, allowing for air flow. Fig. 4 shows the open edges and slots in brackets, including the open bottom edge, open lower side edges, and open top-edge slots 26.

[0037] Figure 5 highlights improved air flow under the heat sink plates and out through the top-edge slots. Air can flow in or out of the openings shown by brackets in Fig. 4. Possible paths for air flow are shown as dashed lines in Fig. 5. Air can enter the open lower side edges near side notches 16, pass in gaps between memory chips and substrate 10 and front plate 30 or back plate 30', and exit through top-edge slots 26. Air can also enter anywhere along the bottom edge near contact pads 12, pass in gaps between memory chips and substrate 10 and front plate 30 or back plate 30', and exit through top-edge slots 26. Air paths may zigzag more than shown, and may flow in reverse directions or take other paths.

[0038] Allowing such air flow between substrate 10 and front plate 30 or back plate 30' provides for greater cooling of front plate 30 and back plate 30', since each can be cooled not just from the exposed outer surfaces, but also from underneath. The memory chips can also be cooled directly by this air flow. While major cooling still occurs

from the exposed outer surfaces of front plate 30 and back plate 30', some additional cooling is provided from underneath. This additional cooling can help even out hot spots and reduce failures, even if the total cooling from underneath is small.

[0039] Figures 6A-B show an alternate embodiment with larger top openings. The top openings can be enlarged so that top attachment portion 53 near the top three rivets 24 is minimized. Also, rather than contact front plate 30 with substrate 10 along the entire top edge as shown in Figs. 3-5, plate-to-substrate contact can be made only near three top edge rivets 24. This can be especially seen in the top view of Fig. 6B, where front plate 50 does not contact substrate 10 in top-edge openings 56. Raised ridge 52 can be reduced in size near top-edge openings 56. The larger top-edge openings 56 provide for greater air flow underneath front plate 50 and back plate 50'.

[0040] ALTERNATE EMBODIMENTS

[0041] Several other embodiments are contemplated by the inventors. For example the heat sink may be made from a variety of heat-conducting materials such as aluminum, aluminum alloy, copper, brass, bronze, stainless steel, etc. A thin thermally conductive double-sided adhesive

tape (such as Tape No. 8815 made by 3M Company) or metal foil may be placed between the tops of the memory chips and the underside of the heat sink to improve contact with the memory chips. Thermally conductive grease or paste (such as G-749 made by Shin-Etsu Micro Si, Inc.) may also be placed between the tops of the memory chips and the underside of the heat sink to improve contact with the memory chips.

[0042] Rather than use rivets, other fasteners could be substituted. For example, small nuts and bolts, or screws and nuts could be used. These fasteners provided secure and fixed attachment rather than wobbly or temporary attachment. Holes for these fasteners can be added to the memory module substrate. These fastener holes are not normally present in a standard memory module.

[0043] The memory module PCB substrate can be made slightly taller than normal to provide additional room for the fastener holes and rivets near the top edge where the heat sink makes contact with the PCB substrate. The substrate height from the bottom (connector) edge to the top edge can be increased by 1/8 to 1/4 of an inch, for example, to allow more room for the top edge of the heat sink to lay flat against the substrate.

[0044] Two, three or four DRAM chips could be stacked together at each chip location on the memory module. Some memories may have more than one chip select (CS) input, and some combination of these chip selects could be used to select the DRAM chips.

[0045] The number of DRAM chips, capacitors, buffers, and other components on each side of the substrate can be varied. Wide or narrow DRAM chips of one, two, four, eight or more bits in width may be substituted. Other kinds of Integrated Circuits (IC's) or chips can be mounted on the substrate too, such as an address or bank decoder, a parity generator, an error detector, and/or a serial programmable device (SPD) for identifying the memory module.

[0046] Memory modules may use improved DRAM's such as synchronous DRAM (SDRAM), double data rate (DDR) SDRAM, second-generation double data rate (DDR2) SDRAM, Rambus DRAM (RDRAM), direct Rambus DRAM (DRDRAM) or synchronous-pipelined DRAM (SPDRAM). Rather than DRAM's, other memory types (SRAM, ROM, EPROM) could be used. Flash memories using electrically-erasable programmable read-only memory (EEPROM) technology, or some other technologies (ferro-electric FRAM, magnetic

or magneto-resistive MRAM, etc.) could be used by the memory modules.

[0047] Terms such as "top edge", "side", "bottom edge", "left", "right", "front surface", and "back surface" are arbitrarily assigned as shown in the Figures and each term could refer to either surface of the module in relation to the notch. Vias of through-holes may provide electrical connection between the surfaces or intermediate layers. These through-holes could be filled in holes or metal traces between layers rather than open holes, and can also be formed during the PCB processing as an integral part of the PCB. Various alternatives in geometries of the heat-sink plates and memory modules could be substituted.

[0048] The invention could be used to stack other kinds of memory chips than DRAM, such as SRAM and flash memories, etc. The invention could be applied to other kinds of modules besides memory modules, and could be used for stacking other kinds of chips such as buffers, registers, latches, processing arrays, etc.

[0049] The electrical assignment of functions or signals to "pins", the metal contact pads along the bottom of the module, is usually determined by an industry standard-setting committee, such as JEDEC. JEDEC specifies the order of the

pins and the size of the module to allow for interchangeability of modules with sockets. Redundant power and ground pins are usually assigned symmetric positions to avoid reversing the power and ground supplies if the module is inserted backwards. DRAM chips are usually connected to a data pin as close to the chip as possible to minimize wiring lengths and signal delays. Older 72-pin modules are being replaced by 168-pin and larger modules. Multi-layer printed circuit board (PCB) substrates can share the power and ground planes with signal traces to reduce the number of layers used from 8 layers to 6 layers or even 4 layers. Many other configurations are possible. Modules with multiple rows of leads, such as dual-in-line-memory modules (DIMMs) can also benefit from the invention.

[0050] The abstract of the disclosure is provided to comply with the rules requiring an abstract, which will allow a searcher to quickly ascertain the subject matter of the technical disclosure of any patent issued from this disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. 37 C.F.R. Sect. 1.72(b). Any advantages and benefits described may not apply to all embodiments of the inven-

tion. When the word "means" is recited in a claim element, Applicant intends for the claim element to fall under 35 USC Sect. 112, paragraph 6. Often a label of one or more words precedes the word "means". The word or words preceding the word "means" is a label intended to ease referencing of claims elements and is not intended to convey a structural limitation. Such means-plus-function claims are intended to cover not only the structures described herein for performing the function and their structural equivalents, but also equivalent structures. For example, although a nail and a screw have different structures, they are equivalent structures since they both perform the function of fastening. Claims that do not use the word "means" are not intended to fall under 35 USC Sect. 112, paragraph 6. Signals are typically electronic signals, but may be optical signals such as can be carried over a fiber optic line.

[0051] The foregoing description of the embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the inven-

tion be limited not by this detailed description, but rather by the claims appended hereto.